

Prediction of Aerodynamic coefficient using genetic algorithm optimized neural network for sparse data

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Abstract

Wind tunnels use scale models to characterize aerodynamic coefficients. Wind tunnel testing can be slow and costly due to high personnel overhead and intensive power utilization. Although manual curve fitting can be done, it is highly efficient to use a neural network to define the complex relationship between variables. Numerical simulation of complex vehicles on the wide range of conditions required for flight simulation requires static and dynamic data. Static data at low Mach numbers and angles of attack may be obtained with simpler Euler codes. Static data of stalled vehicles where zones of flow separation are usually present at higher angles of attack require Navier-Stokes simulations which are costly due to the large processing time required to attain convergence. Preliminary dynamic data may be obtained with simpler methods based on correlations and vortex methods; however, accurate prediction of the dynamic coefficients requires complex and costly numerical simulations.

A reliable and fast method of predicting complex aerodynamic coefficients for flight simulation is presented using a neural network. The training data for the neural network are derived from numerical simulations and wind-tunnel experiments. The aerodynamic coefficients are modeled as functions of the flow characteristics and the control surfaces of the vehicle. The basic coefficients of lift, drag and pitching moment are expressed as functions of angles of attack and Mach number. The modeled and training aerodynamic coefficients show good agreement. This method shows excellent potential for rapid development of aerodynamic models for flight simulation.

Genetic Algorithms (GA) are used to optimize a previously built Artificial Neural Network (ANN) that reliably predicts aerodynamic coefficients. Results indicate that the GA provided an efficient method of optimizing the ANN model to predict aerodynamic coefficients. The reliability of the ANN using the GA includes prediction of aerodynamic coefficients to an accuracy of $\pm 10\%$. In our problem, we would like to get an optimized neural network architecture and minimum data set. This has been accomplished within 500 training cycles of a neural network. After removing training pairs (outliers), the GA has produced much better results. The neural network constructed is a feed forward neural network with a back propagation learning mechanism. The main goal has been to free the network design process from constraints of human biases, and to discover better forms of neural network architectures. The automation of the network architecture search by genetic algorithms seems to have been the best way to achieve this goal.